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DYNAMICS OF GAS-SURFACE INTERACTIONS-INSTRUMENTATION  
(U) CHICAGO UNIV IL JAMES FRANCK INST S J SIBENER  
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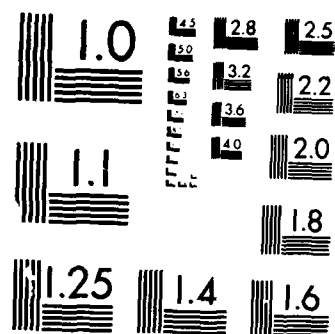
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DoD-URIP Proposal AFOSR-85-0061

Final Technical Report

January 1, 1985 - December 31, 1985

Submitted by Steven J. Sibener  
The James Franck Institute  
and Department of Chemistry  
The University of Chicago  
Chicago, Illinois 60637

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Chief, Technical Information Division

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## ABSTRACT

This instrumentation grant was used to procure several pieces of equipment which significantly enhanced research capabilities for studying the interactions of molecular beams and laser radiation with well defined surfaces in an ultra-high vacuum environment. A partial listing of the topics that are being explored in greater as a direct result of the new instrumentation includes surface phonon spectroscopy, the dynamics and energetics of heterogeneous interactions, thin film growth including nucleation in two-dimensional systems, gas-surface energy transfer, gas-surface interaction potentials, and a variety of laser-surface processes such surface photochemistry (radical reactions, desorption, ablation), energy transfer, and photoemission. The instrumentation has directly enhanced research efforts that are DoD supported (AFOSR and ONR).

## OVERVIEW

During the past year we have been very active in adding two new research instruments to our DoD funded research programs. One of these is a new high energy resolution ( $\leq 200\mu\text{eV}$ ) UHV molecular beam-surface scattering apparatus, which is currently being assembled and tested. The other instrument is a novel electron energy loss spectrometer, which is currently under construction. These instruments will give us unique capabilities for studying the vibrational properties of surfaces, including mapping out the surface phonon dispersion relations for both the acoustic and optical phonon modes which are present on a variety of clean and adsorbate covered surfaces. These instruments will also have wide applicability for studying many other surface processes, such as laser-surface interactions (surface photochemistry) and real-time surface kinetics.

This instrument grant was specifically used to procure several pieces of equipment for our new neutral particle and electron scattering instruments. The next section of this Final Technical Report includes a description of each of the items that were purchased with this grant. Detailed descriptions of the research topics that are being studied with these instruments can be found in recent three-year and annual renewal proposals associated with the following DoD supported research efforts: AFOSR-84-0073 and ONR N00014-77-C-0240.

#### PERSONNEL

Our research group currently consists of eight graduate students, one postdoctoral fellow, and an outstanding undergraduate. Listed in order of seniority, these include: Dr. Wesley Natzle, Kevin Gibson, Yaw-Wen Yang, Barbara Gans, David Padowitz, Suzanne King, Warren Menezes, Daniel Koleske, Glenn Tisdale, and Scott Silence. In April 1986 Larry Brown will also join our group as a postdoctoral fellow from Princeton University.

As in the past, close collaborations are continuing between our experimental group and several theoretical groups. These are efforts guided by Professor John Light (quantum scattering calculations) and by Professors Doug Mills, John Black, Michael Klein, and Lou Bruch (lattice dynamics calculations). New collaborations are getting underway with Professors B. Gerber (scattering from partially disordered surfaces), M. Cole (adsorption potentials), and K. Freed (laser induced desorption).

#### INSTRUMENTATION

##### A) Closed Cycle Helium Refrigeration System

An Air Products closed cycle helium refrigeration system having 2 watts of cooling power at 9 K was procured for cooling a unique cryogenic nozzle in our new high resolution neutral particle scattering apparatus. For low temperature

operation, the beam gas is precooled to 80 K by the first cooling stage of this unit, and then further cooled down to 10 K by the second stage of the refrigerator. This beam source has the special advantage that it can easily be operated at nozzle temperatures between 10 K and 300 K, allowing us to *dial the de Broglie wavelength* of the beam in a straightforward manner. This new beam source will be especially useful for inelastic phonon scattering experiments involving very soft modes. It will also greatly assist us in carrying out diffraction and selective adsorption experiments--offering in particular higher sensitivity to subtle features of gas-surface interaction potentials. The unit is in place and is fully operational.

B) Boostivac Ion Pump

This combined ion pump/sublimation pump was procured from the Perkin-Elmer corporation, and is being used for evacuating the crystal chamber of our new high resolution neutral particle scattering apparatus. It is in place and is fully operational.

C) Excimer Laser

A Lambda Physics MSC-103 excimer laser was purchased with this instrument grant for conducting several different optical experiments in our laboratory. It can generate intense pulses of laser radiation in the visible and UV, down to wavelengths as short as 157nm. It also includes a microprocessor controlled power stabilization circuit (one of the first delivered to the U.S.), and can operate in several optical arrangements including as an unstable resonator (better divergence properties). It can run at repetition rates as high as 200 Hz. It is being used for an unusually broad range of experiments, including, for example, sampling real-time surface concentrations of adsorbates via flash desorption, creating laser-annealed surfaces, producing pulsed molecular beams of radicals and other highly reactive species, cleaning cryogenically cooled

samples, and conducting surface photochemistry experiments (desorption, photoemission, etc...). We hope to add a dye laser to this system in order to add wavelength tunability to our capabilities, as will be required, for example, for resonant multiphoton ionization analysis of energy disposal in inelastic and reactive scattering experiments. The excimer laser is currently in place and is fully operational.

D) Single Pass Cylindrical Mirror Auger Electron Optics

This electron energy analyzer was purchased for conducting Auger spectroscopy measurements in our new electron-energy loss spectrometer chamber. It was fabricated by the Physical Electronics Corporation, and has an internally mounted high energy electron gun which is needed for Auger analysis. It's main purpose will be for monitoring the cleanliness of our sample surfaces before, during, and after experimental runs. This analyzer recently arrived in our laboratory, and is being prepared for installation in our new UHV chamber.

E) High Resolution Electron Energy Loss Spectrometer

The electron optics for our new "beam-EELS" apparatus were purchased from LK Technologies due to the superb design they came up with, which met many of our special requirements: a rotating energy analyzer, high electron transmission,  $\leq 5$  meV resolution, and especially a primary beam energy which could be varied from 0 to  $\geq 200$  eV. We in fact worked closely with this new company so that many of our specific needs were designed into the spectrometer from the start. It is scheduled for delivery in late April, 1986.

The capabilities of this novel EELS instrument will nicely complement those of our neutral particle scattering program. It will in particular allow us to map out the surface phonon dispersion relations for high energy optical phonons for clean and adsorbate covered surfaces. It will also allow



us to study reaction intermediates and mechanisms due to its coupling with a molecular beam line. This "beam-EELS" combination means that real-time measurements will be possible i.e., the EELS spectrometer will examine the surface vibrations that are present following pulsed dosing of the surface by a variety of molecules. We shall also be able to study the adsorption states that are accessed by incident molecules as a function of translational or internal energy.

#### PRESENTATIONS

Invited seminars were presented by Steven J. Sibener at the following locations during the time period 1 November, 1984 - 31 March, 1986:

Iowa State University, Department of Chemistry, Ames, Iowa  
Cornell University, Department of Physics, Ithaca, New York  
University of Colorado-Boulder, Department of Chemistry,  
Boulder, Colorado  
Tenth International Symposium on Molecular Beams, Cannes, France  
Dow Chemical U.S.A., Midland, Michigan  
Faraday Discussion of the Royal Society of Chemistry: Physical  
Interactions and Energy Exchange at the Gas-Solid Interface,  
McMaster University, Hamilton, Ontario, Canada  
International Conference on Phonon Physics, Budapest, Hungary  
IVth International Conference on Vibrations at Surfaces,  
Bowness-On-Windermere, England  
Purdue University, Department of Chemistry, West Lafayette, Indiana

#### PUBLICATIONS

Our efforts associated with this new DoD-URIP supported program have been exclusively devoted to apparatus fabrication, assembly, and testing during the past year. Accordingly, no publications have yet resulted from this work.

DoD CONSULTING

The Principal Investigator recently became a member of the Defense Science Study Group, a new DARPA funded effort, which is being administered through the Institute for Defense Analyses.

SUMMARY

We would like to emphasize in closing that the DoD-URIP grant that was awarded certainly achieved its goal of updating and enhancing the research capabilities of our surface science research program. Several of the components that were purchased were essential to the construction of our new high resolution neutral particle scattering instrument. Furthermore, the ability to add an advanced EELS spectrometer to our laboratory, which was until recently viewed as the key missing element of our program, will certainly allow us to address many new scientific questions which are central to our work.

7  
STEVEN J. SIDENER

Born

April 3, 1954; Brooklyn, New York

Education

1971-1975 University of Rochester, Rochester, New York.  
Sc.B. in Chemistry awarded with High  
Distinction, 1975.  
B.A. in Physics awarded with Distinction, 1975.  
1975-1979 University of California, Berkeley.  
M.S. in Chemistry, 1977.  
Ph.D. in Chemistry, 1979.  
Research with Professor Yuan T. Lee.

Professional Experience

Eastman Kodak Research Laboratories, Photographic Research  
Division, Summer 1974: Electrostatic properties of  
polymers and polymer-metal interfaces.

Eastman Kodak Research Laboratories, Physics Division,  
Solid State Physics Research Laboratory, Summer 1975:  
Oxide growth on GaAsP for MOS fabrication.

Bell Laboratories Postdoctoral Fellow,  
September 1979 - August 1980.  
Research with Dr. M. J. Cardillo involving molecular  
beam scattering from single crystal surfaces.

Assistant Professor of Chemistry, The James Franck Institute  
and The Department of Chemistry, The University of Chicago,  
August 1980 - June 1985.

Associate Professor of Chemistry, The James Franck Institute  
and The Department of Chemistry, The University of Chicago,  
July 1985 - .

Honors and Awards

Vice Chairman, 1985 Gordon Conference on the Dynamics of  
Gas-Surface Interactions  
IBM Faculty Development Award, 1984-86  
Alfred P. Sloan Foundation Research Fellow, 1983-87  
Camille and Henry Dreyfus Young Faculty in Chemistry  
Award, 1980  
Gulf Oil Research Fellow,  
University of California, Berkeley  
American Institute of Chemists Award,  
University of Rochester  
American Chemical Society Division of Colloid and Surface  
Chemistry  
Undergraduate Thesis Competition Honorable Mention:  
"The Shape of Liquid Interfaces," 1975.  
Regional Scholar for New York City,  
University of Rochester  
New York State Regents Scholar

Associations

Phi Beta Kappa  
American Physical Society  
Royal Society of Chemistry  
Sigma Xi  
AAAS

Consulting

Dow Chemical USA  
Teltech Resource Network  
Defense Science Study Group-IBA

Professional Activities  
and Major Committee  
Assignments

Vice-Chairman, 1985 Gordon Conference on the Dynamics of Gas-Surface Interactions

Chairman, Chemistry Computation Committee (charged with running a departmental facility, which includes a VAX780 and an FPS164). October 1983 - October 1985.

Member, University Committee on Academic Computing

Member, University Committee on Distributed Computing

END

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